

Overview of the Energy and Power Evaluation Program (ENPEP-BALANCE)

Guenter Conzelmann

*Center for Energy, Environmental, and Economic
Systems Analysis (CEEESA)*

Decision and Information Sciences Division (DIS)

Argonne National Laboratory

9700 South Cass Avenue

Argonne, IL 60439

(ph) ++1-630-252-7173

(fax) ++1-630-252-6073

(email) guenter@anl.gov

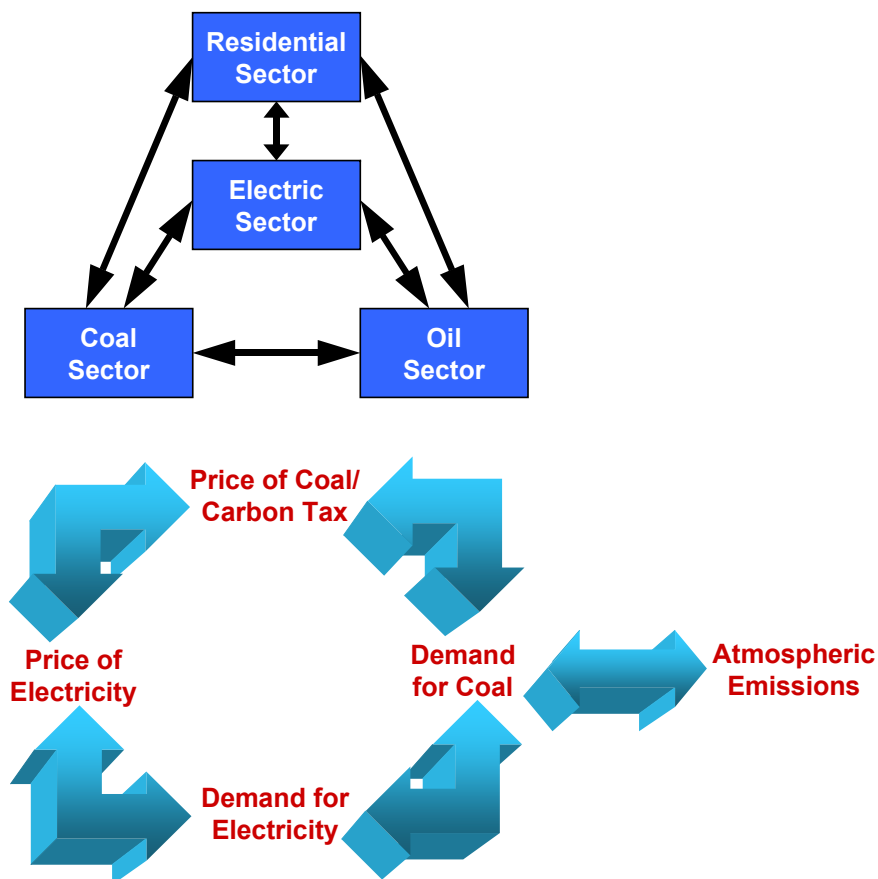
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ENPEP-BALANCE is Designed to Analyze the Entire Energy System in an Integrated Framework

- Reveal cross-sectoral effects; provide structure for consistent energy “planning” program
- Integrated framework allows evaluation of feedback effects



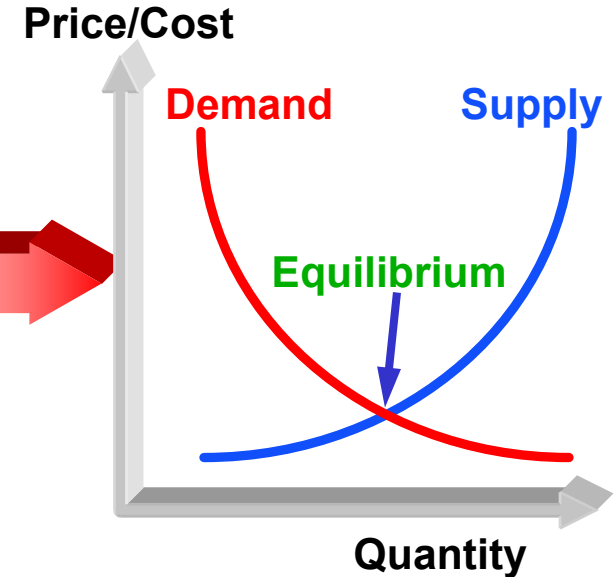
ENPEP-BALANCE Determines the Equilibrium Supply/Demand Balance of the Energy System

INPUT

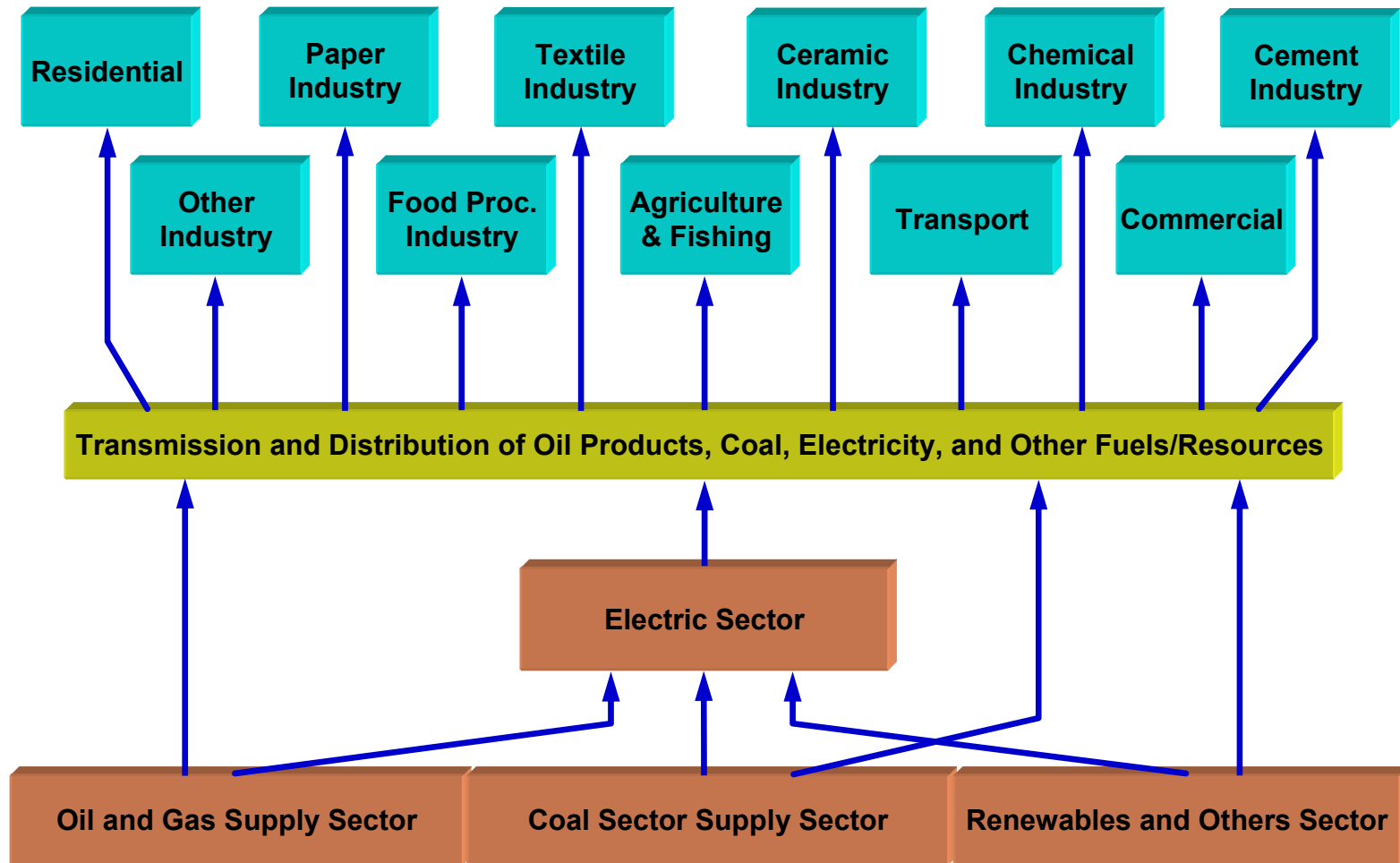
- Energy system structure
- Base year energy flows and prices
- Energy demand growth projections
- Technical and policy constraints



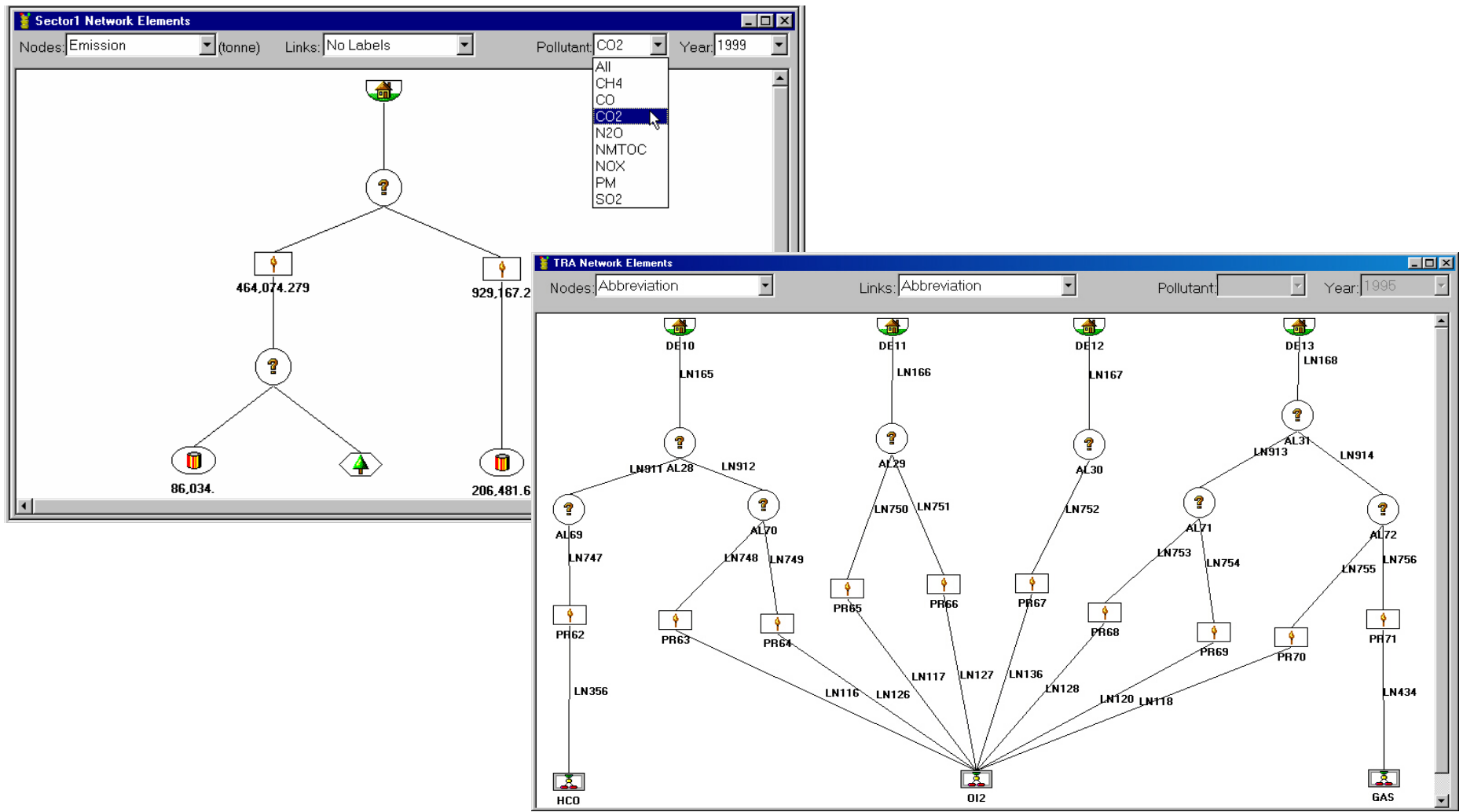
OUTPUT



ENPEP-BALANCE Uses an Energy Network to Simulate Energy Markets



Using **Nodes** and **Links**, Each Sector is Modeled Differently Depending on Data Availability and Type of Issue Analyzed

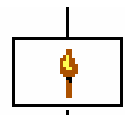


The Following Node Types are Available to Model Different Energy Activities

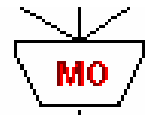
■ Demand



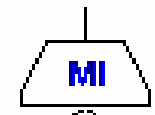
■ Conversion Processes



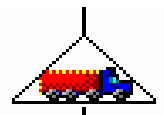
Single In-/Output



Multi Output



Multi Input

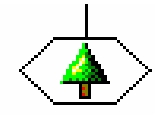


Transport

■ Resource Processes



Depletable



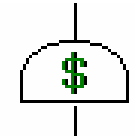
Renewable

■ Economic Processes

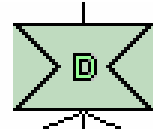
■ Electricity Dispatch and Thermal and Hydro Units



Decision/Allocation



Pricing



Central Dispatch

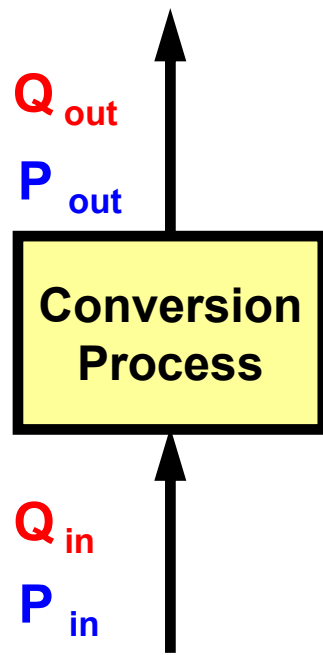


Thermal Unit



Hydro Unit

Nodes Are a Series of Simple Sub-Models, Each With a Set of Quantity and Price Equations



- $\text{Price}_{\text{output}} = f(\text{Price}_{\text{input}})$

- Example conversion process

$$\text{Revenue} = \text{Cost}$$

$$Q_{\text{out}} \times P_{\text{out}} = Q_{\text{in}} \times P_{\text{in}} + \text{O\&M} + \text{Capital Recovery}$$

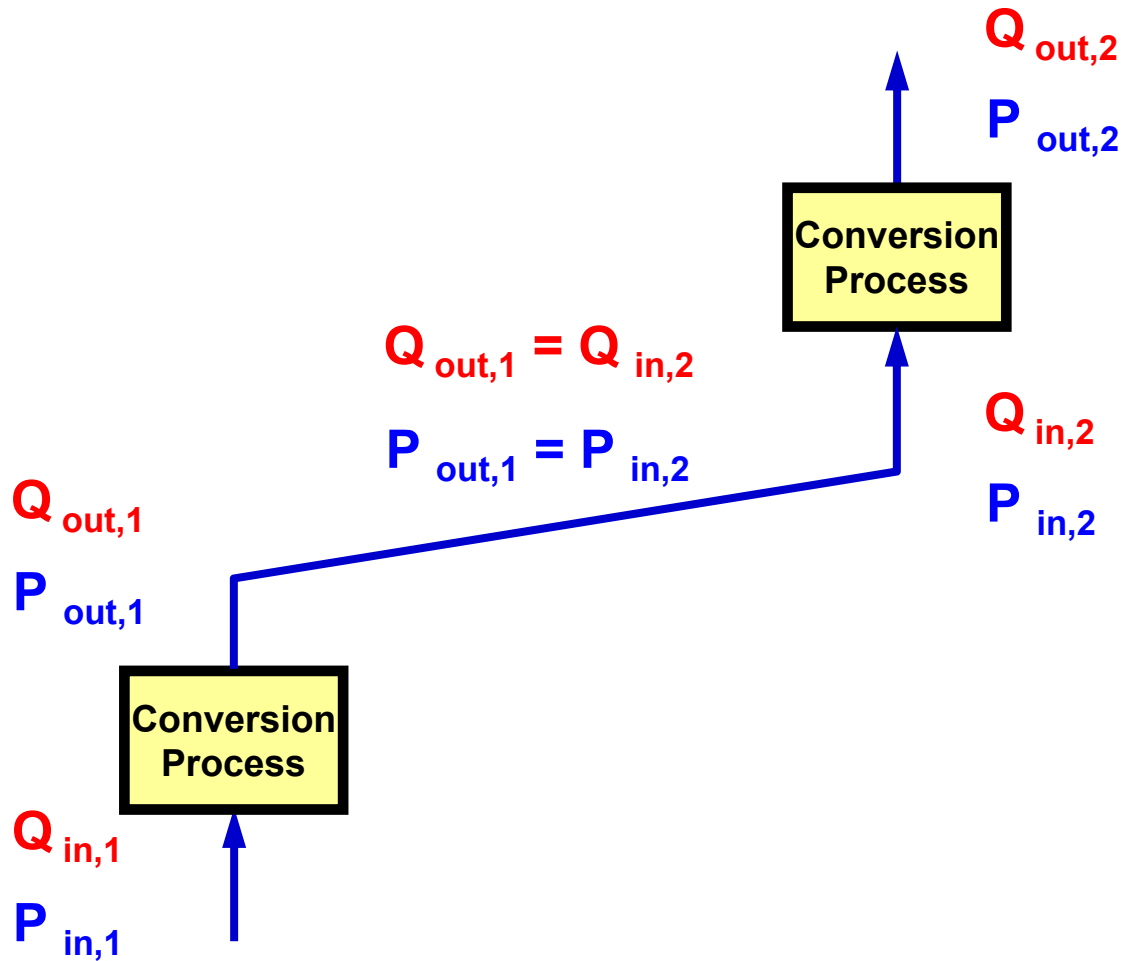
- $\text{Quantity}_{\text{output}} = f(\text{Quantity}_{\text{input}})$

- Example conversion process

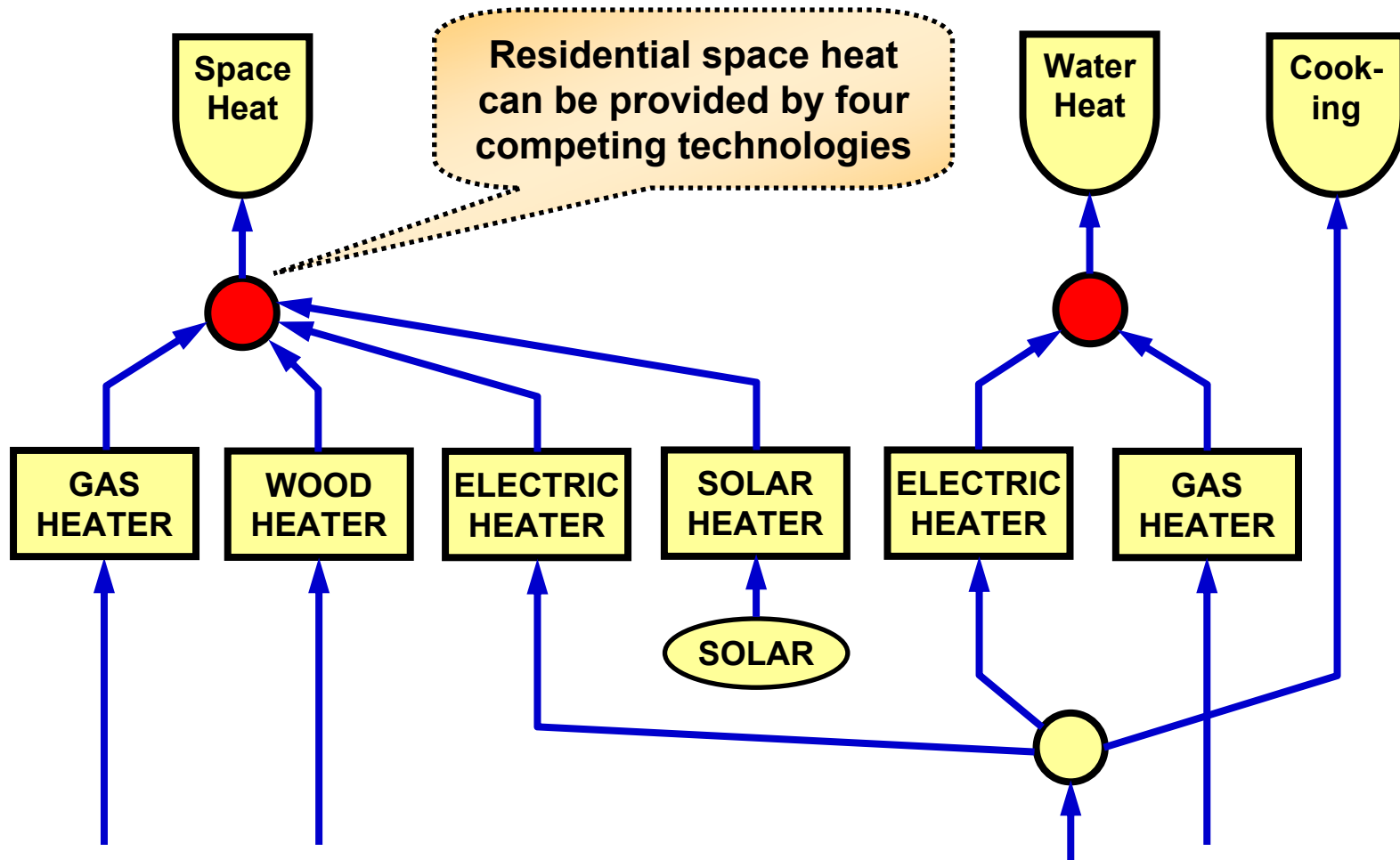
$$Q_{\text{out}} = Q_{\text{in}} \times \gamma$$

γ : conversion efficiency

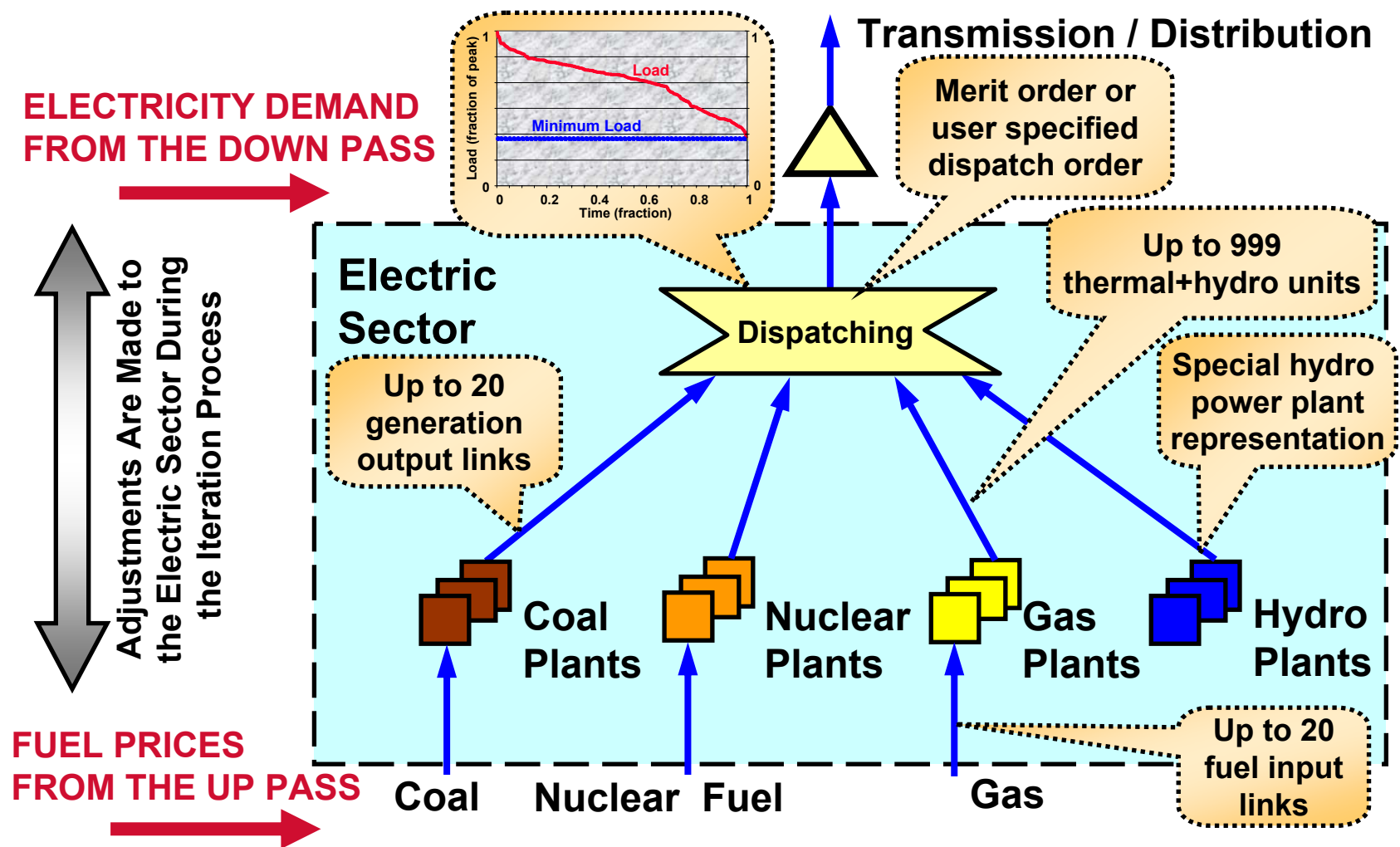
The Links Connect the Nodes and Pass Information from One Node to Another



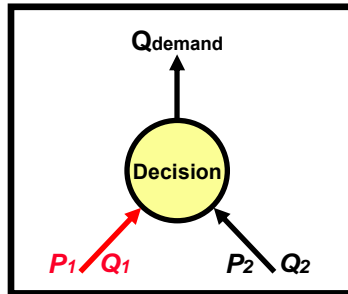
At the Decision Nodes, Fuels and Technologies Compete for Future Market Shares



The Electricity Dispatch Node Handles the Electric Sector in a Special Way

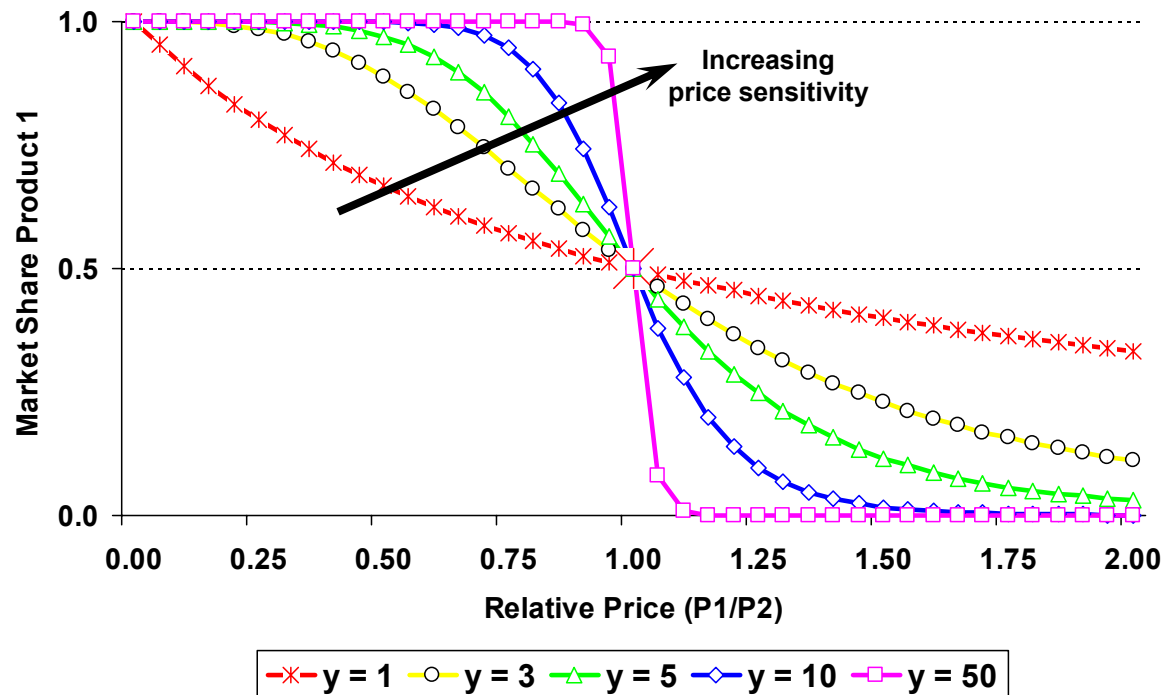


ENPEP-BALANCE Uses a Logit-Function to Estimate Market Shares of Competing Commodities at the Decision Node



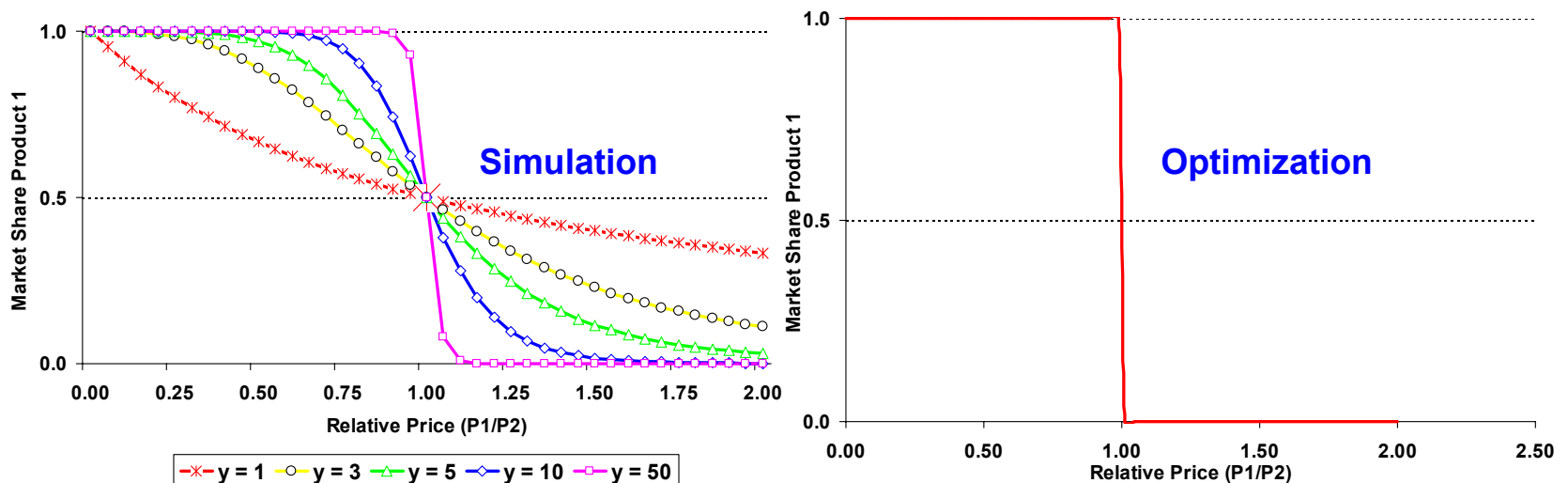
$$MS_1 = \frac{Q_1}{Q_1 + Q_2} = \frac{\left[\frac{1}{P_1 \times PM_1} \right]^\gamma}{\left[\frac{1}{P_1 \times PM_1} \right]^\gamma + \left[\frac{1}{P_2 \times PM_2} \right]^\gamma}$$

γ price sensitivity for this decision process
MS: market share
P: price
PM: premium multiplier
Q: quantity

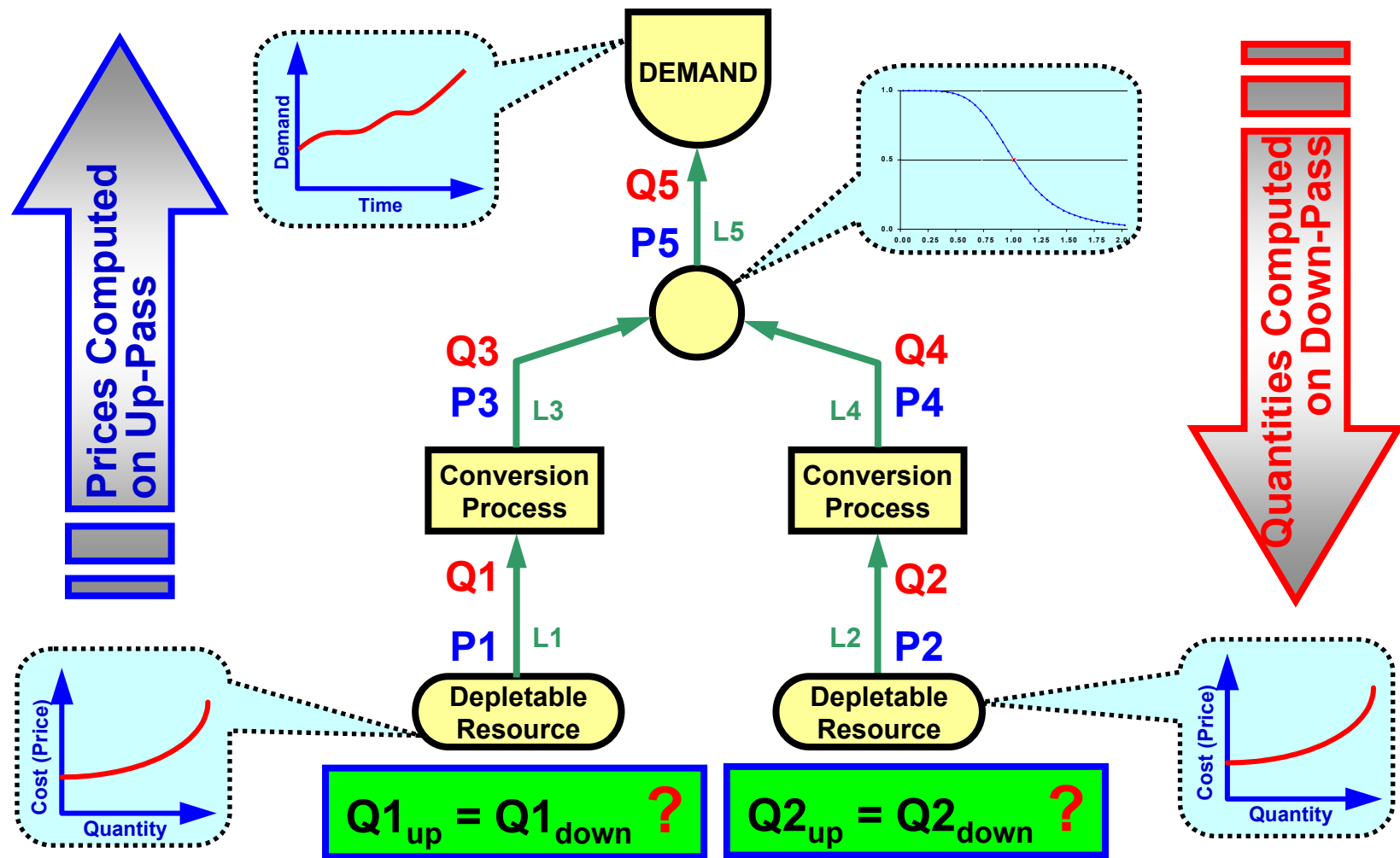


The ENPEP-BALANCE Nonlinear Equilibrium Algorithm is Based on Decentralized Decision Making

- Market share calculation assumes “ideal market” subject to government policies, fuel availability, and market constraints
- A lag factor accounts for delays in capital stock turnover
- The result is a nonlinear, market-based equilibrium solution within policy constraints, not a simple, linear optimization
- No single person or organization controls all energy prices and decisions on energy use
- All decision makers optimize their energy choices based on their own needs and desires



ENPEP-BALANCE Uses an Up/Down Pass Sequence and the Jacobi Iterative Technique to Determine the Market Clearing Prices and Quantities (Market Equilibrium)



The Up-Pass and Down-Pass Tell the Model in Which Sequence to Perform the Calculations (Which Node Comes When)

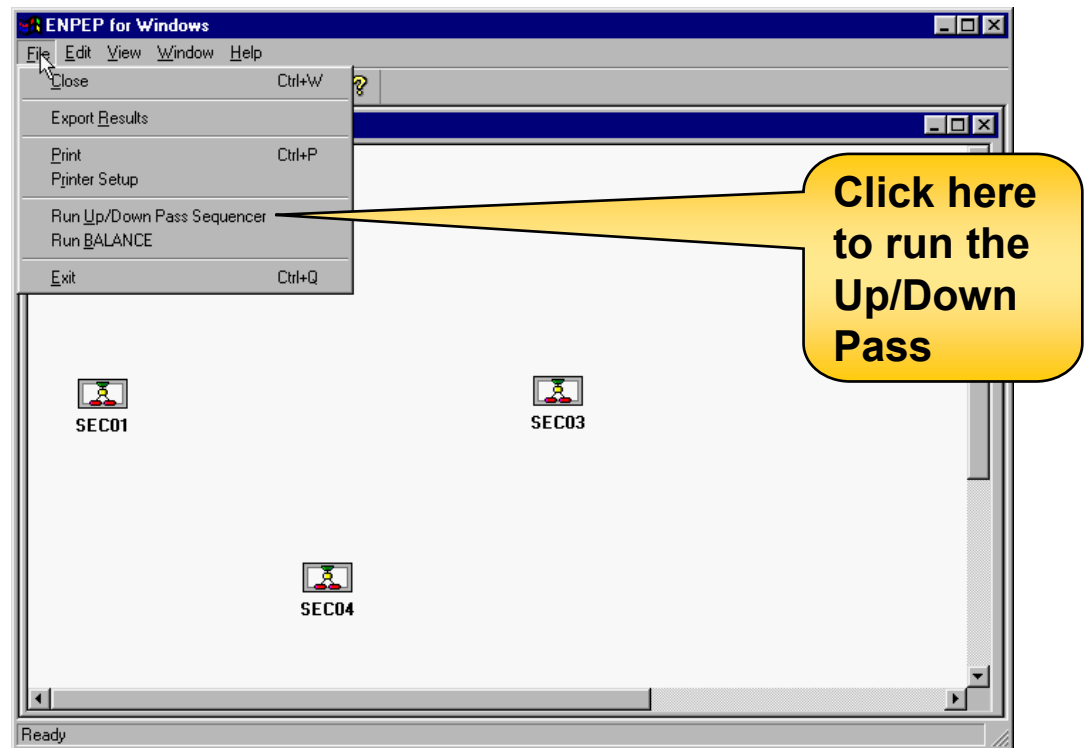
- Up-Pass and Down-Pass Sequences are repeated until convergence is achieved

CONVERGENCE IS ACHIEVED WHEN:

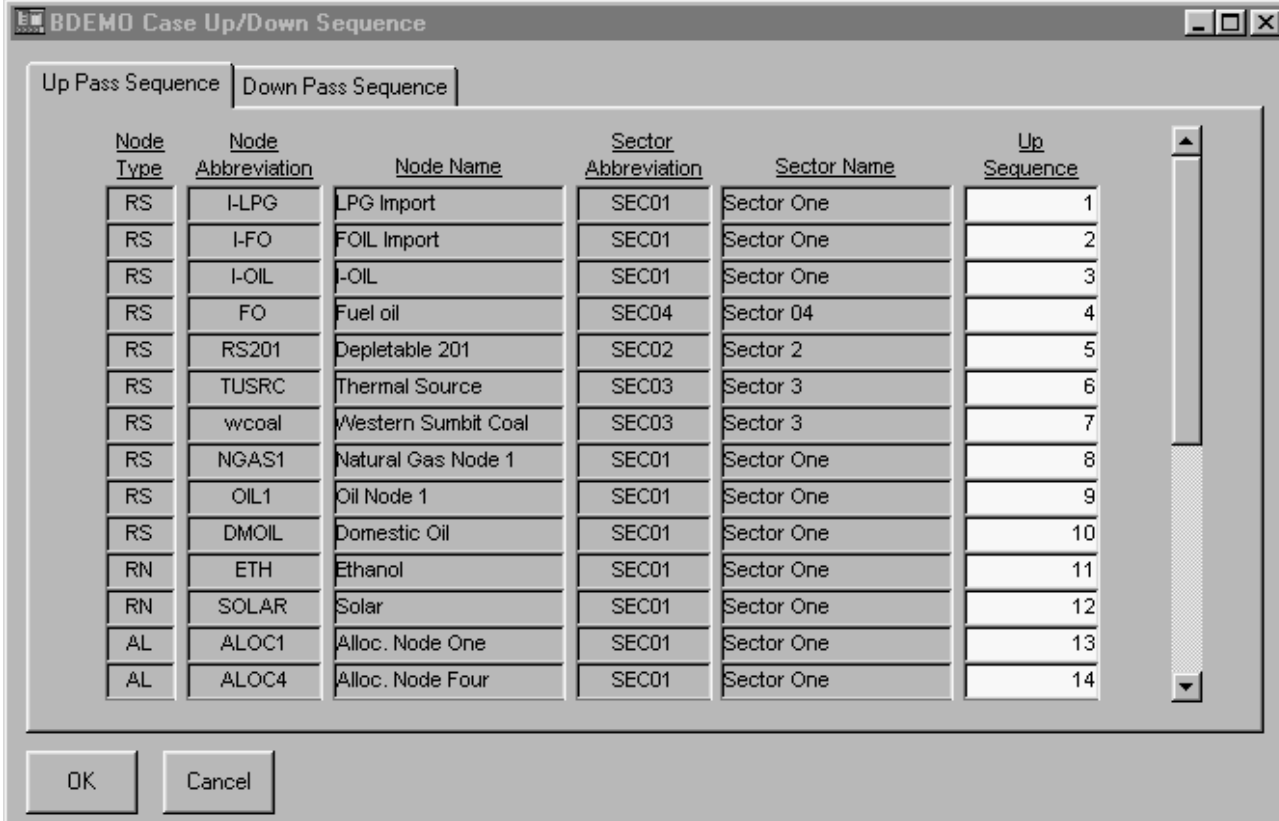
- $Q1 \text{ (down)} = Q1 \text{ (up)} \pm \text{Tolerance Level}$
- $Q2 \text{ (down)} = Q2 \text{ (up)} \pm \text{Tolerance Level}$
- The final result is a converged solution
- The solution is in equilibrium across the whole network

Execution of the Up and Down-Pass Sequencer in ENPEP-BALANCE

- Run the Up/Down Pass Sequencer before running ENPEP-BALANCE for the first time
- This will determine the “node visitation sequence”
- Later, the Up/Down Pass must be executed only if there has been a **CHANGE IN THE STRUCTURE** of the energy network
 - Add/delete nodes
 - Add/delete links



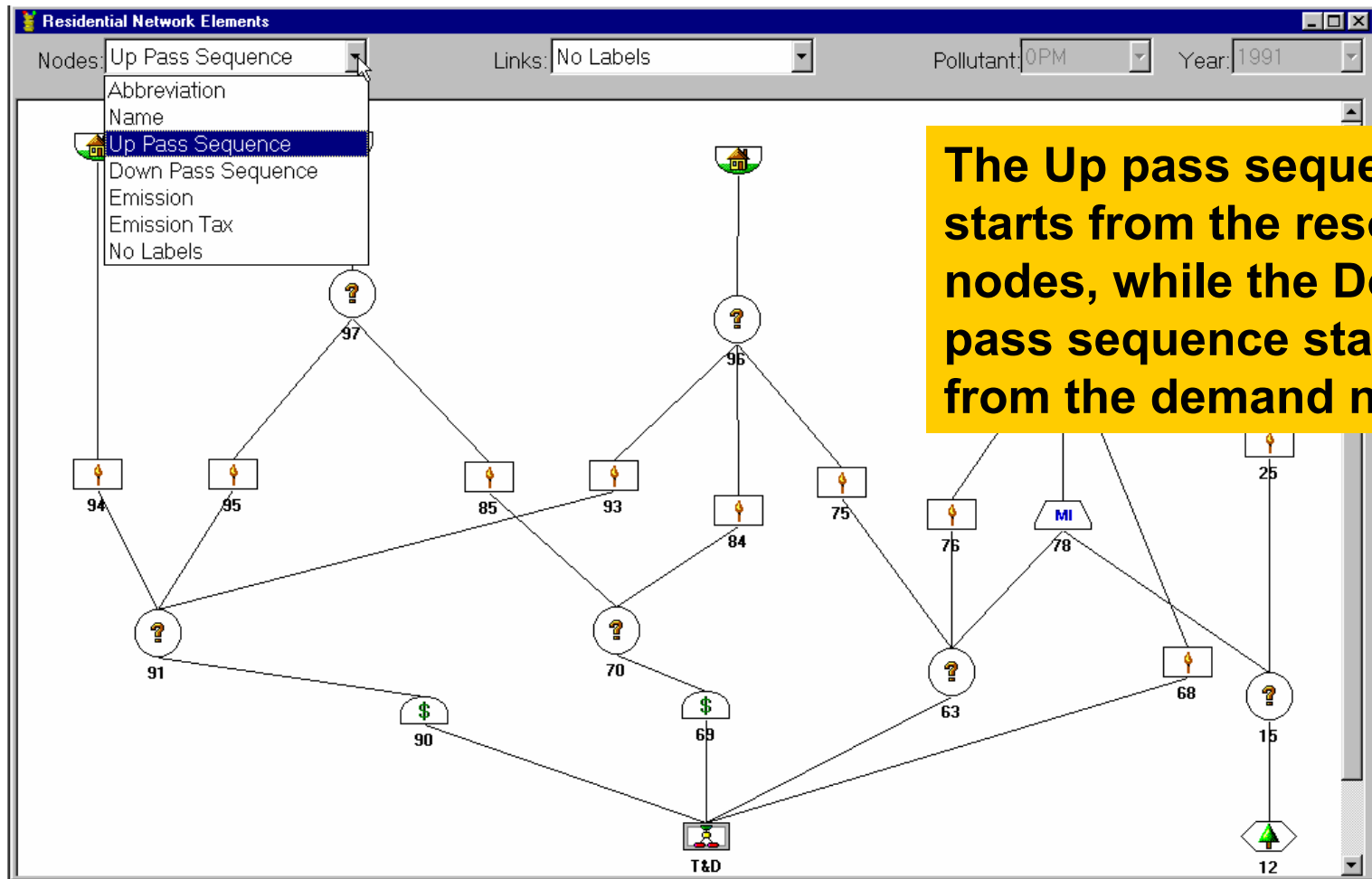
The Calculated Up/Down Node Visitation Sequence Can Be Viewed in Tabular Form



Up Pass Sequence		Down Pass Sequence			
<u>Node Type</u>	<u>Node Abbreviation</u>	<u>Node Name</u>	<u>Sector Abbreviation</u>	<u>Sector Name</u>	<u>Up Sequence</u>
RS	I-LPG	LPG Import	SEC01	Sector One	1
RS	I-FO	FOIL Import	SEC01	Sector One	2
RS	I-OIL	I-OIL	SEC01	Sector One	3
RS	FO	Fuel oil	SEC04	Sector 04	4
RS	RS201	Depletable 201	SEC02	Sector 2	5
RS	TUSRC	Thermal Source	SEC03	Sector 3	6
RS	wcoal	Western Summit Coal	SEC03	Sector 3	7
RS	NGAS1	Natural Gas Node 1	SEC01	Sector One	8
RS	OIL1	Oil Node 1	SEC01	Sector One	9
RS	DMOIL	Domestic Oil	SEC01	Sector One	10
RN	ETH	Ethanol	SEC01	Sector One	11
RN	SOLAR	Solar	SEC01	Sector One	12
AL	ALOC1	Alloc. Node One	SEC01	Sector One	13
AL	ALOC4	Alloc. Node Four	SEC01	Sector One	14

This screen also allows the user to manually adjust the node visitation sequence, if necessary.

The Up/Down Node Visitation Sequence Can Be Viewed Directly in the Network



Each Case Study Can be Stored in a Different Database

The screenshot shows the 'BALANCE for Windows' application window. It features a menu bar (File, Edit, Window, Help) and a toolbar. The main area is a table with three columns: 'Study name', 'Last Opened', and 'Description'. The table lists several databases, including 'demo', 'vietnam-iaea', 'Mexico Electric Ag', 'Mexico Electric Sector', and 'Mexico Electric'. At the bottom, there are buttons for 'Ok', 'Cancel', 'Delete', 'New', and 'Add'. Three yellow callout boxes provide instructions: one points to the 'Study name' column with the text 'Here is the path and name of the database file'; another points to the 'New' button with the text 'Create a new (blank) database'; and a third points to the 'Add' button with the text 'Add an existing database to this list'.

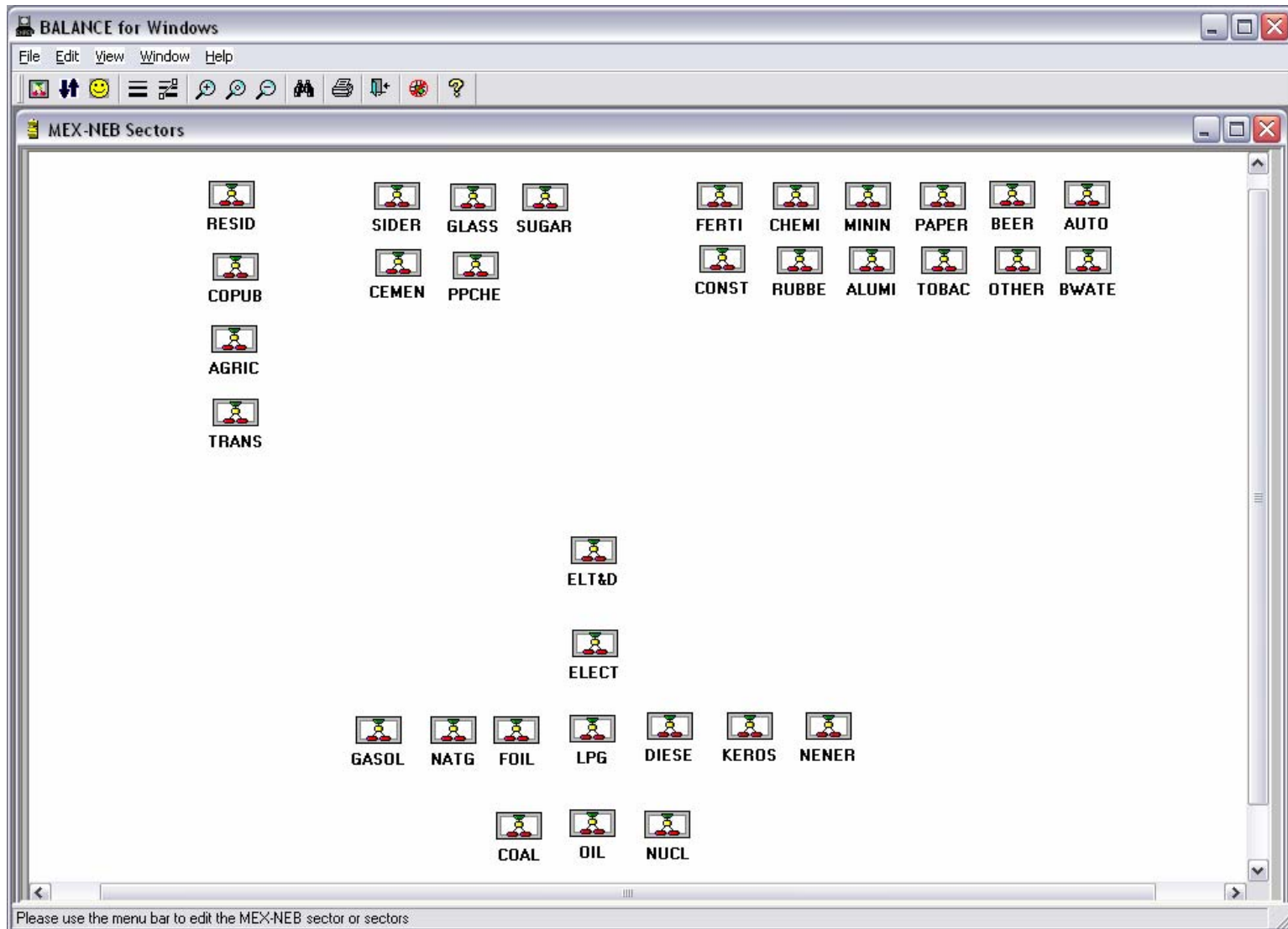
Study name	Last Opened	Description
demo	10/3/2002	This database contains two demonstration cases
vietnam-iaea	9/13/2002	Database with Vietnam GHG cases: Base Case, DSM Case, Efficiency Case, Nuclear Case
Mexico Electric Ag		Database with Mexican Electric Power Sector Case
Mexico Electric Sector	9/13/2002	
Mexico Electric	9/13/2002	

Buttons: Ok, Cancel, Delete, New, Add

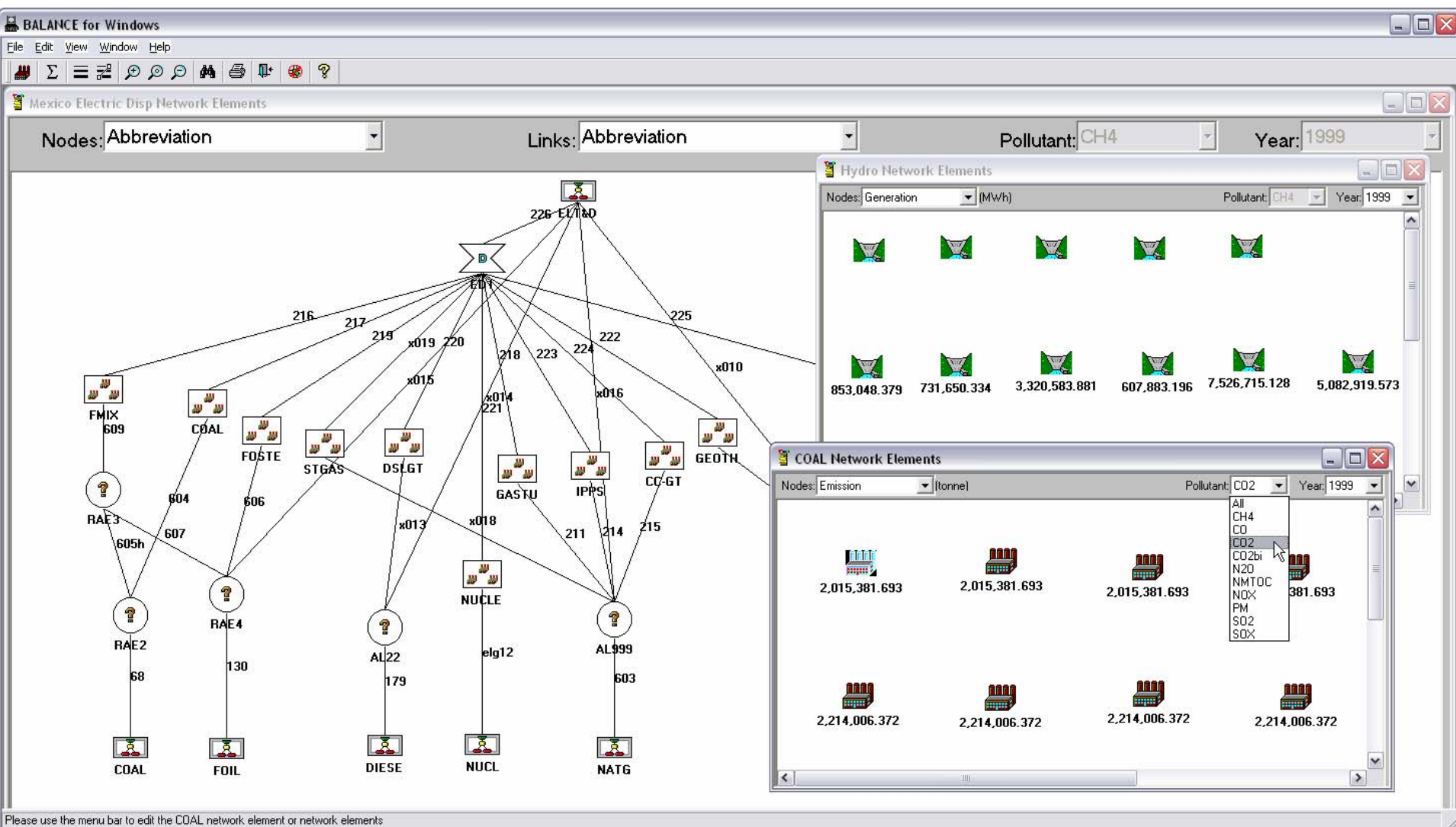
Callouts:

- Here is the path and name of the database file
- Create a new (blank) database
- Add an existing database to this list

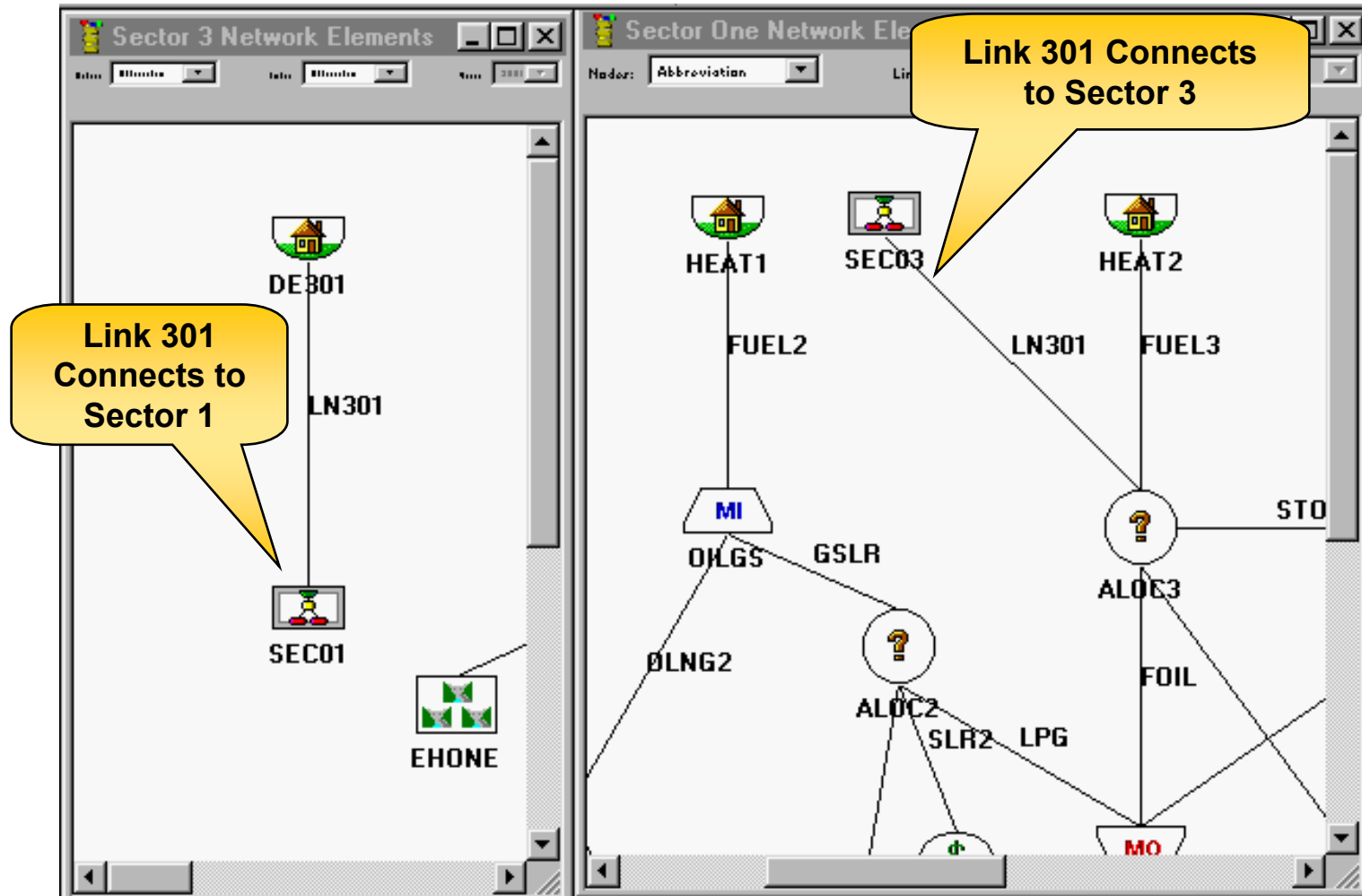
The First Step in Developing an ENPEP-BALANCE Network is to Define the Sectors Included in Your System



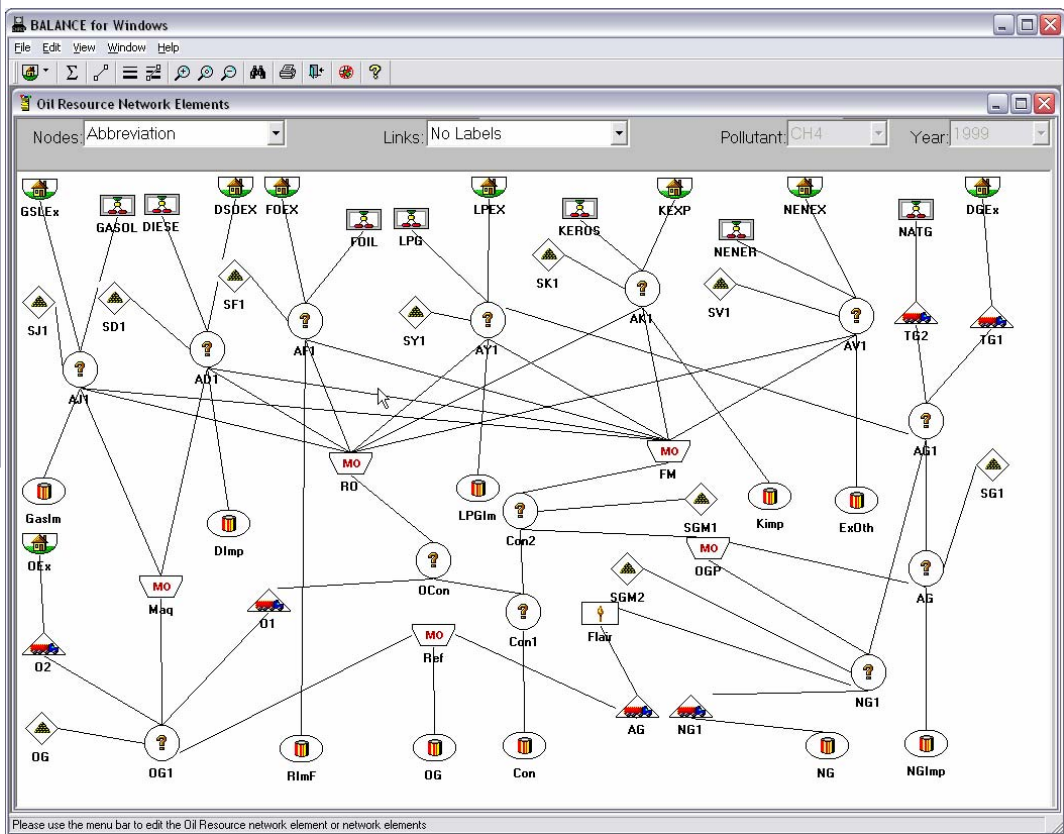
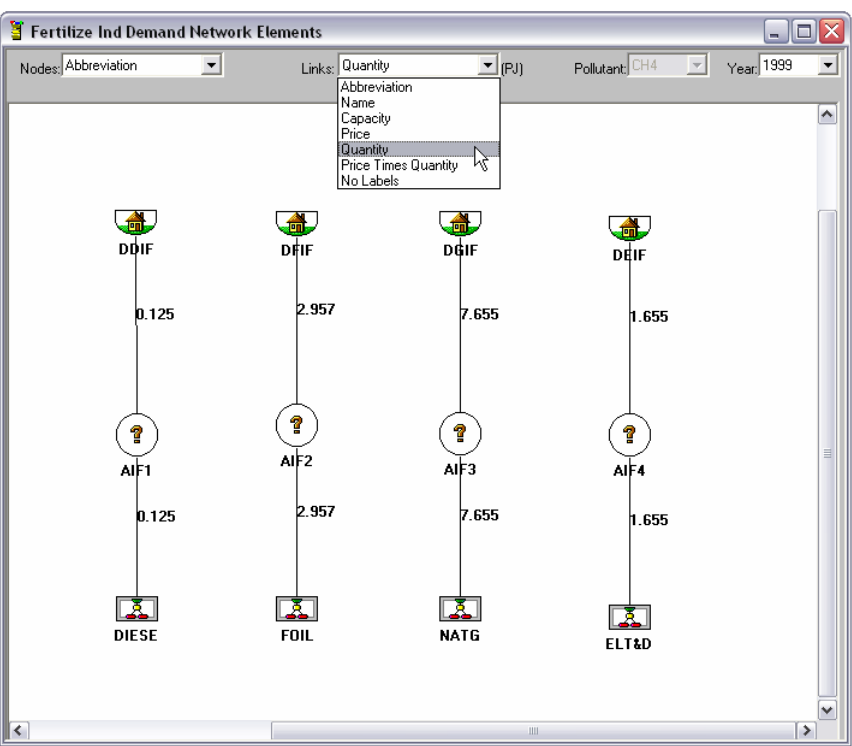
Each Sector May be Modeled Differently Depending on Data Availability and Type of Issue Analyzed: Power Sector Can Be Modeled at the Unit Level



Intersectoral Links Can Connect Energy Networks of Different Sectors



The Level of Detail May Vary from Simple to Complex: Example: Simple Fertilizer Industry and More Complex Oil & Gas Sector



All Network Elements in ENPEP-BALANCE Can Be Accessed Using a Standardized Simple Menu

BALANCE for Windows

File Edit Window Help

Glass Network Elements

Nodes: Abbreviation Links: A

HeatG 391

LPB1 CR1

PIG5 PIG2 PIG1 PIG3 PIG8

144

PIG6

202 531

LPG NENER COAL

DIESE

FOIL

124

AIG6

AIG8

AIG2

AIG1

369 370 367

386 388

173

391

PIG4 Conversion Process Node Properties

Technical Properties Economic Properties Emissions Properties

Year	Single Plant Output Capacity (PJ)	All Plants Output Capacity (PJ)	Typical Capacity Factor (Fraction)	Output/Input Ratio (Fraction)
1999	12.390	100,000,000.000	0.750	1.000
2000				

PIG2 Conversion Process Node Properties

Technical Properties Economic Properties Emissions Properties

Year	Single Plant Capital Investment (\$1000)	Operating and Maintenance Cost (\$/GJ)	Life Expectancy (Years)	Interest Rate (Fraction)
1999	27,000.000	0.128	30.00	0.100
2000				
2001				
2002				
2003				
2004				
2005				
2006				
2007				
2008				
2009				

PIG6 Conversion Process Node Properties

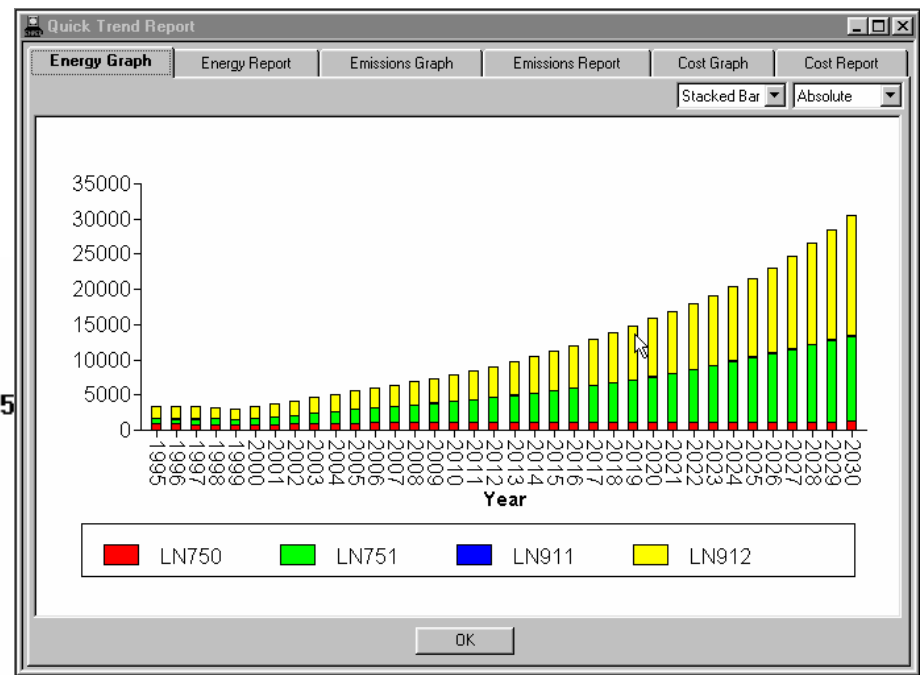
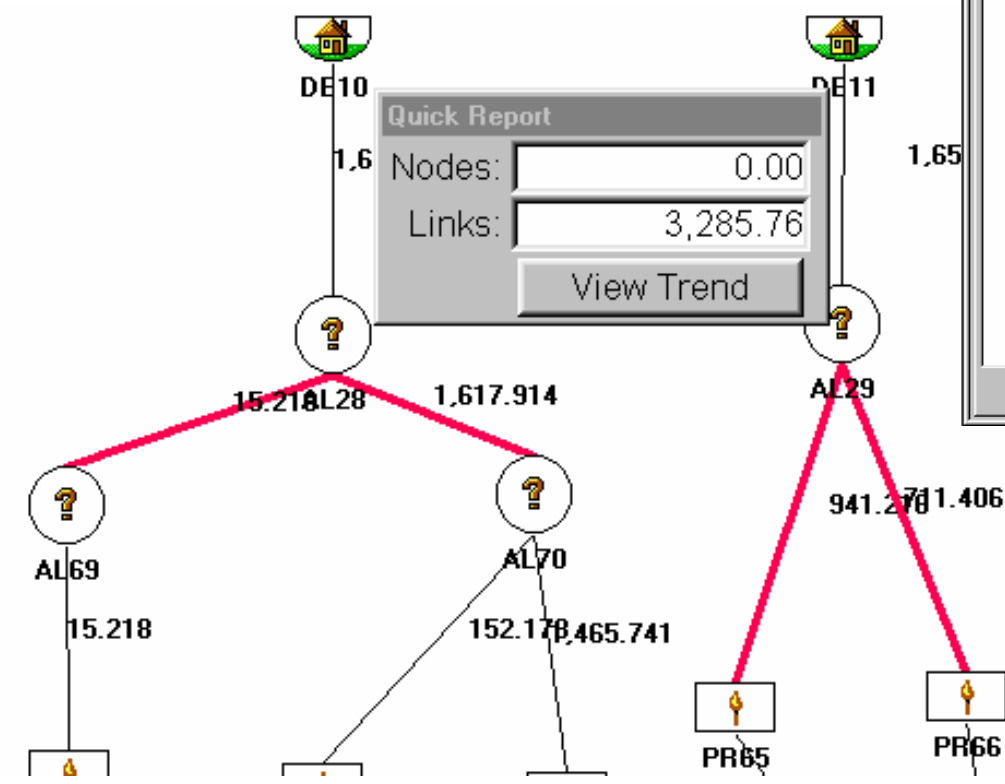
Technical Properties Economic Properties Emissions Properties

Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
1999	CH4	0.003			
	CO	0.015			
	CO2	77.367	Carbon		
	CO2bi		Carbon		
	N2O	0.000			
	NMTOC	0.005			
	NOX	0.170			
	PM	0.082	Ash		
	SO2	0.995	Sulfur		
	SOX	1.410	Sulfur		
2000	CH4				

OK Cancel Duplicate Up Column Duplicate Down Column

Ready

Results Can be Viewed Interactively for Individual Network Components and the Entire System



ENPEP-BALANCE Uses a Standard Methodology to Determine the Uncontrolled and Controlled Source Emissions



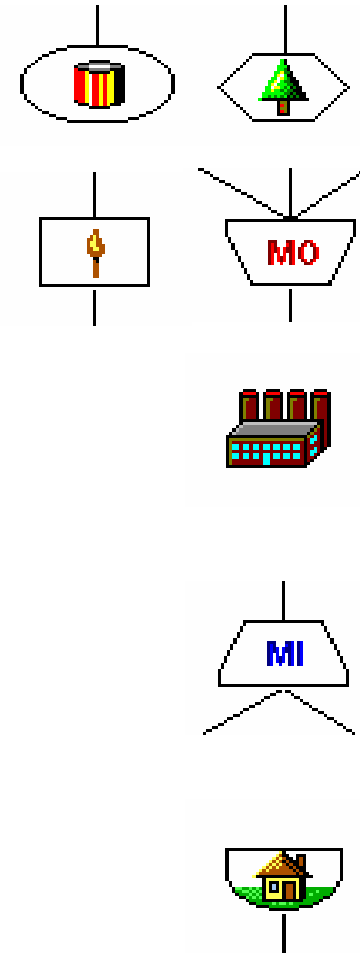
$$\text{Uncontrolled Emissions} = \text{Fuel Consumption} \times \text{Emission Factor} \times \text{Chemical Scale}$$

$$\text{Controlled Emissions} = \text{Uncontrolled Emissions} \times (100 - \text{Control Efficiency}) / 100$$

Emissions Are Calculated and Reported by Node for any Pollutant the User Specifies

Run Parameters	Pollutants	Pollution Controls	Output Codes	Non-electric Units	Electric Units																								
<table border="1"> <thead> <tr> <th>Name</th> <th>Abbreviation</th> <th>Chemical Scale</th> </tr> </thead> <tbody> <tr> <td>Methane</td> <td>CH4</td> <td></td> </tr> <tr> <td>Carbon Dioxide</td> <td>CO2</td> <td>Carbon</td> </tr> <tr> <td>Nitrous Oxides</td> <td>N2O</td> <td></td> </tr> <tr> <td>Non Methane Total Organic Compounds</td> <td>NMTOC</td> <td></td> </tr> <tr> <td>Nitrogen Oxides</td> <td>NOX</td> <td></td> </tr> <tr> <td>Particulate Matter Total</td> <td>PM</td> <td>Ash</td> </tr> <tr> <td>Sulfur Dioxide</td> <td>SO2</td> <td>Sulfur</td> </tr> </tbody> </table>						Name	Abbreviation	Chemical Scale	Methane	CH4		Carbon Dioxide	CO2	Carbon	Nitrous Oxides	N2O		Non Methane Total Organic Compounds	NMTOC		Nitrogen Oxides	NOX		Particulate Matter Total	PM	Ash	Sulfur Dioxide	SO2	Sulfur
Name	Abbreviation	Chemical Scale																											
Methane	CH4																												
Carbon Dioxide	CO2	Carbon																											
Nitrous Oxides	N2O																												
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Nitrogen Oxides	NOX																												
Particulate Matter Total	PM	Ash																											
Sulfur Dioxide	SO2	Sulfur																											
<div>Carbon Monoxide</div> <div>CO</div>																													
<div>OK</div> <div>Cancel</div> <div>Add</div> <div>Delete</div>																													

Technical Properties					
Economic Properties					
Emissions Properties					
Control Properties					
Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
1999	CH4	0.001			
	CO2	1.349	Carbon	77.60	20.00
	N2O	0.002			
	NMTOC	0.001			
	NOX	0.399			
	PM	0.184	Ash	17.50	
	SO2	0.698	Sulfur	4.50	100.00

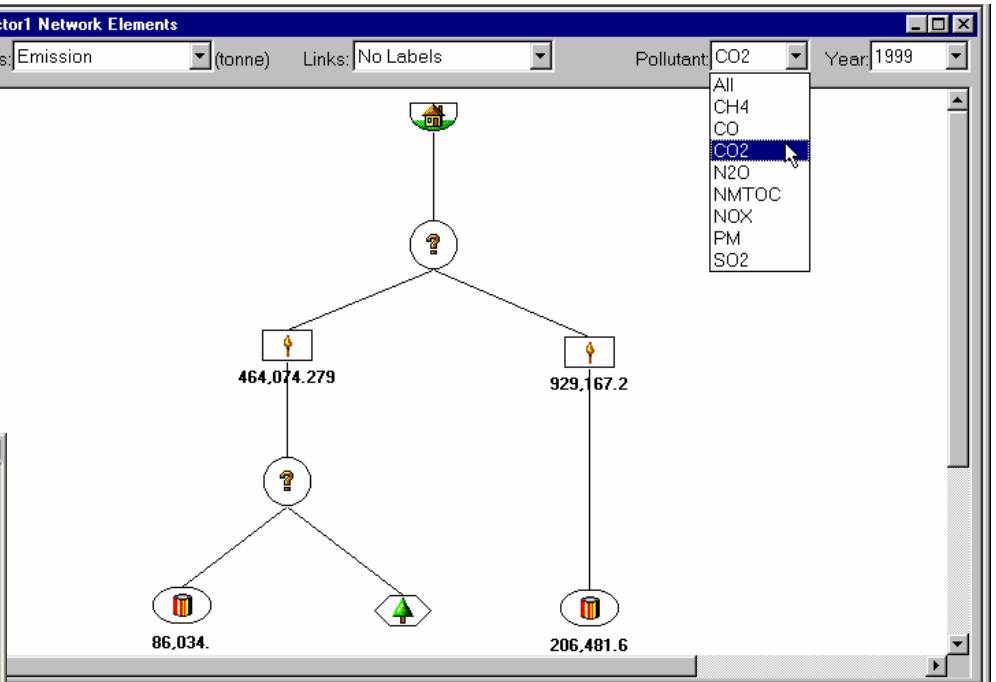
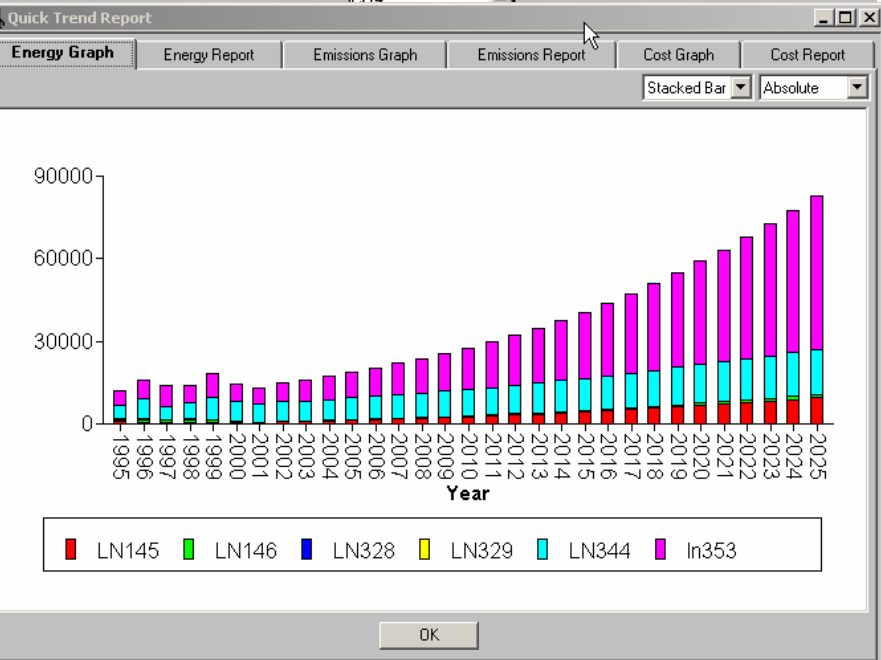


Environmental Results Can be Viewed Directly in the Network, in Tables, Simple Graphs, or Exported to EXCEL

Energy Report | Energy Graph | Environmental Report | Environmental Graph

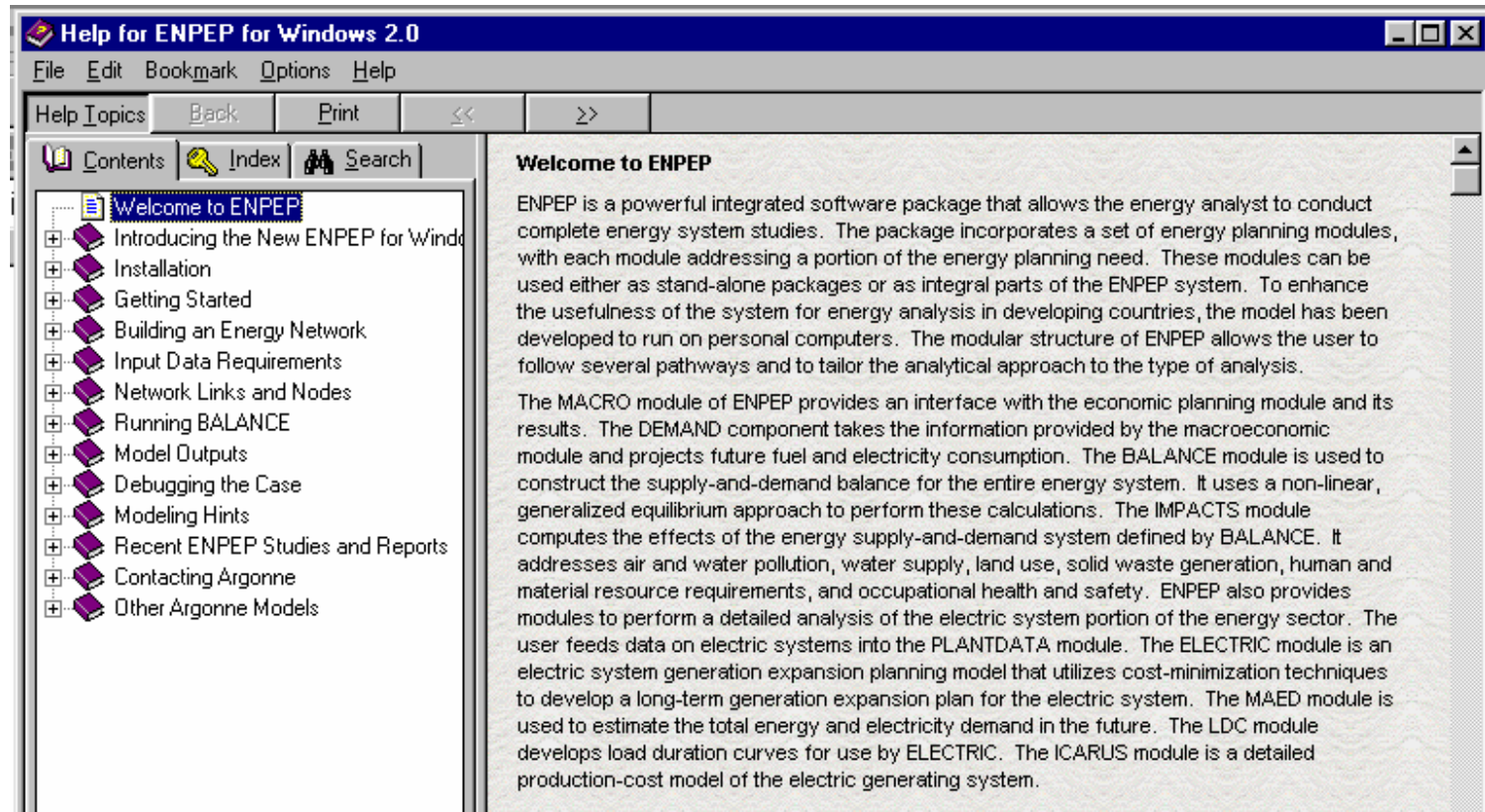
Year	Input Quantity (kBOE)	Pollutant Abbreviation	Emission Factor Times Scale Value (kg/GJ)	Emissions (tonne)
1999	1200	CO2	104.64515	720,243.281
2000	1245.777588	CO2	104.64515	747,719.114
2001	1292.328003	CO2	104.64515	775,658.800
2002	1340.535767	CO2	104.64515	804,593.232
2003	1389.497192	CO2	104.64515	833,980.013
2004	1439.415039	CO2	104.64515	863,940.841

Selected Pollutant: CO2
CH4



	A	B	C	D	E	F	G	H
1	DemoC Export to TXT Nodes emissions				13-Feb-01	11:40		
2								
3	Base	Nb of	Nb of	Nb of				
4	Year	Years	Nodes	Pollutants	Unit			
5								
6	1991	30	79	10	tonne			
7								
8								
9	Sector	Node	Type	Pollutant	1991	1992	1993	1994
10	AG	DE23	DE	OPM	1658.296	1741.211	1822.874	1906.544
11	AG	DE23	DE	1PM10	0	0	0	0
12	AG	DE23	DE	2SO2	14.31514	15.0309	15.73585	16.45812
13	AG	DE23	DE	3NOX	282.5357	296.6624	310.5759	324.8314

A Help System is Available to Provide Online Support

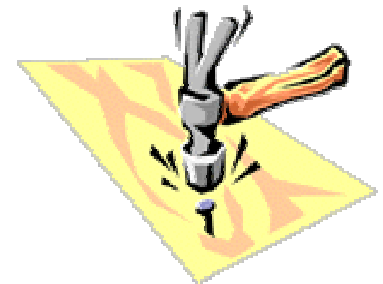


Note: The help system is still under construction. Content will change and not all topics may be available at this time.

Energy System Modeling in ENPEP-BALANCE: Model Limitations

As with all models, ENPEP-BALANCE has its limitations:

- The market share formula needs to be applied carefully to produce realistic results (particularly from transition from 1st to 2nd year)
- The solution is generated year-by-year and is said to be “myopic”
 - However, in today’s short-term oriented energy market, this may actually be an advantage
- It is demand-driven
- If not set up in sufficient detail, it can be insensitive to price
- The ease of use in the WINDOWS interface conceals the sub-models!
- Nevertheless, the ENPEP-BALANCE approach is proved to be powerful and useful if applied correctly;
- ENPEP-BALANCE is a tool - and a tool should be used wisely



ENPEP-BALANCE is Used by Energy and Environmental Experts Worldwide to Analyze a Variety of Critical Issues

■ Electric system analysis

- expansion analysis, demand side management
- optimal hydro/thermal dispatch (\$, environment)
- deregulation, independent power producers, power market studies, interconnection studies, etc.



■ Total energy system

- overall energy sector development strategies
- natural gas market analysis
- energy conservation+efficiency



■ Environmental analysis

- emissions projections for PM, SO₂, NO_x, etc.
- emissions reduction strategies for PM, SO₂ and NO_x
- emissions trading for SO₂ and CO₂ (cap and trade)
- GHG mitigation studies and Kyoto Mechanisms
- waste generation, land use, water pollution



Information on ENPEP-BALANCE Applications is Available on our Website

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CEEESA works with the World Bank and Mexico's Power Company CFE on Wind Power Analysis using the WASP Model ++ Late

What's New at CEEESA

Power
Gas Infrastructure
Energy
Environment
Technology
Macroeconomics
Policy

A recent ENPEP analysis for Mexico shows the country to substantially increase its reliance on natural gas for its energy needs potentially leading to a supply-demand imbalance... [\(more\)](#)

The newest version of GTMax now has the capability to interface with SCADA systems to run the model with real-time data... [\(more\)](#)

CEEESA modeling results show substantial economic benefits of integrating Southeast Europe's power markets... [\(more\)](#)

Featured Program: Modeling The Evolution of a Hydrogen Infrastructure

Like other infrastructures, the H2 production and delivery infrastructure is unlikely to evolve smoothly and predictably but rather in "fits and starts", much like a complex adaptive system. In addition to technological uncertainties, the complex interaction environment created by the diverse objectives, decision rules, and operating procedures of the many participants (or agents) in the H2 marketplace will play a major role in system evolution. CEEESA collaborates with other researchers in using various modeling and simulation techniques to analyze the complex development and evolution of a new hydrogen infrastructure... [\(more\)](#)

Transferring data from www.dis.anl.gov...

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ENPEP Applications

ENPEP is used by CEEESA staff members as well as energy and environmental ministries, lending agencies, electric utilities, research institutes, and energy regulatory commissions around the world. Model applications cover the entire spectrum of issues found in today's complex energy markets:

- energy policy analysis
- energy market projections
- natural gas market analysis
- carbon emissions projections
- projections of criteria pollutants (SO2, NOX, etc.)
- carbon mitigation studies
- power market studies
- deregulation issues

Increasingly, model applications focus on climate-change-related issues. ENPEP climate change study reports can be downloaded at various web sites, including the United Nations Framework Convention on Climate Change ([UNFCCC](#)) and the U.S. Environmental Protection Agency ([EPA](#)).

Click on the map below to get more information on ENPEP applications by region. You can also click on the names of the regions ([North/South America](#), [Asia](#), [Africa](#), [Europe](#)).

